The Responses of *Tegula funebralis* to Starfishes and Predatory Snails

(Mollusca : Gastropoda)

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(2 Tables)

INTRODUCTION

The responses of some gastropods to predators are well known (Bullock, 1953; Clark, 1958; Feder, 1956; Smith, 1960). This study was designed to investigate the responses of a single herbivorous snail, *Tegula funebralis* (A. Adams, 1854), to a number of predatory and related forms. They include: the sea stars *Pisaster ochraceus* (Brandt, 1835), *Pisaster brevispinus* (Stimpson, 1857), *Pisaster giganteus* (Stimpson, 1857), *Patiria miniata* (Brandt, 1835), *Pycnopodia helianthoides* (Brandt, 1835), *Leptasterias aequalis* (Stimpson, 1862), *Dermasterias imbricata* (Grube, 1857), and the carnivorous snails *Thais emarginata* (Deshayes, 1839), and *Acanthina spirata* (Blainville, 1832). All of these animals occur in the rocky intertidal zone, at Mussel Point, Pacific Grove, California, with the exception of *Pisaster brevispinus,* which is found in the nearby sandy subtidal zone. Hereafter the name *Tegula* will refer to *Tegula funebralis* only.

CONTACT EXPERIMENTS

Feder, (1956) and Bullock, (1953) indicate that the tube feet of starfishes, when they are placed in contact with a snail, elicit a greater response from gastropods than do any other portions of the starfish body. The responses of *Tegula* to the tube feet of most of the starfishes tested are essentially the same as those described by Feder, (1956 pp 143-145) for *Pisaster ochraceus* and *Tegula.* If a *Tegula* is stimulated in the head region the snail rears back, raising its head and the anterior portion of its foot. This is followed by a turn of approximately 90 degrees and the snail crawls away rapidly. Lateral stimulation of the foot and epipodium causes a tipping or twisting of the shell away from the point of contact and the snail either turns away or crawls obliquely away. Contact with the posterior portion of the foot results in the shell being tipped far up over the head and is often accompanied by violent rocking of the shell through an arc of almost 180 degrees. As before, the snail crawls away at 2 or 3 times normal speed. In the following contact experiments a tube foot, excised from a test starfish, was slipped over the end of a probe and touched to various soft parts of *Tegula.* All of the tube feet were of the grasping type, taken from the middle ⅓ of a starfish ray.

Contact with the sole of the foot of the carnivorous snails *Thais emarginata* and *Acanthina spirata* produces a greater response in *Tegula* than a similar touch with their shell, proboscis, or tentacles. Therefore, in tests with these species, small pieces of the foot were applied to *Tegula* in the manner used for the tube feet of sea stars.

The responses elicited by contact with the foot of *Thais emarginata* or *Acanthina spirata* were essentially the same as those following contact with starfish tube feet with one exception. A *Tegula* stimulated laterally or posteriorly first twists its shell away from the area of stimulation, but instead of crawling away it raises its head and foot and turns toward the point of contact, crawling up onto the predator tissue. Placing a shell of the carnivore in the path of the *Tegula* causes it to climb rapidly onto the shell.

The responses enumerated above were not merely reactions to any foreign object. Contact with a clean bare probe only causes a *Tegula* to retract that part of its body which has been touched and to clamp its shell down tightly against the substrate.

Each predator was tested against 50 *Tegulas,* 25 of which were stimulated first with the control probe and

then the predator tissue. The order of applying the two stimuli was reversed for the other 25. The *Tegulas* tested ranged in size from 5 mm to 30 mm in maximum basal diameter of the shell. To avoid any possible habituation to the various stimuli, each *Tegula* was taken from the shore, used once, and then returned to the beach.

In Table 1 responses to contact with both predator tissue and the control (probe) are indicated. All responses were typical of the descriptions above but varied in intensity. A strong response consists of an immediate reaction following a single stimulus. Moderate responses are those in which the reaction was slower and more than one application of the stimulus was required. Where no response is recorded the animal completely ignored the stimulus. The test animals are listed in the table in order of strength of response elicited, the strongest first.

DIFFUSION EXPERIMENTS

Physical contact between *Tegula* and predatory starfishes is not always necessary to produce a response on the part of the mollusk (Bullock, 1953; Feder, 1956). To further test the hypothesis that substances diffusing from a predator can cause a reaction in *Tegula* the following series of experiments was performed. A clean, plastic dishpan was filled to a depth of 6 cm with fresh sea water, and 25 *Tegulas*, ranging in basal shell diameter from 5 mm to 30 mm, were aligned on the periphery of the bottom. Five minutes later the number of snails with their heads out of water was recorded, and the same snails were again placed along the bottom of the pan. A predator was placed in the center of the pan and the number of snails with their heads out of water at the end of 5 minutes was again noted. The snails were used in only one experiment (including control) and each experiment was repeated 5 times. When necessary the predator was placed in a plastic bag to prevent contact with the *Tegulas*. Because of the small size of a few of the predators, several were placed in a cage and used at one time.

Table 1

The Responses of *Tegula funebralis* to Contact with Predator Tissue and with a Clean Probe

Predator	Response of *Tegula funebralis* to contact with:							
	Predator Tissue				Clean Probe			
	S	M	W	O	S	M	W	O
Pisaster giganteus	94	4	2	0	6	82	12	0
Pisaster ochraceus	88	10	2	0	16	70	14	0
Acanthina spirata	84	12	4	0	6	82	12	0
Pisaster brevispinus	80	12	8	0	10	84	6	0
Thais emarginata	76	20	4	0	26	70	4	0
Pycnopodia helianthoides	64	32	4	0	16	76	8	0
Leptasterias aequalis	44	38	16	2	12	80	8	0
Dermasterias imbricata	0	0	14	86	6	84	10	0
Patiria miniata	0	0	8	92	6	88	6	0

Figures are percentages of animals tested which gave the response indicated. N = 50, S = Strong response, M = Moderate response, W = Weak response, and O = No response

Table 2

The Responses of *Tegula funebralis* to Diffusible Substances from Predators

Predator	Trial				
	1	2	3	4	5
Pycnopodia helianthoides	19/4	4/0	17/1	19/0	13/0
Pisaster giganteus	11/1	6/2	19/3	6/2	9/0
Pisaster ochraceus	17/3	5/1	8/0	7/3	5/0
Leptasterias aequalis	10/1	8/1	4/1	11/1	8/1
Pisaster brevispinus	3/0	6/0	5/0	13/0	5/0
Acanthina spirata	0/1	4/1	2/1	3/0	1/2
Thais emarginata	0/0	0/0	0/0	4/1	2/4
Patiria miniata	0/0	2/0	1/0	0/1	1/1
Dermasterias imbricata	1/0	1/1	0/0	1/1	0/1

Experimental situation/Control situation. Figures represent the number of *Tegula funebralis* with heads out of water at the end of five minutes; N = 25 for each trial.

Animals used in this manner were *Leptasterias aequalis* (16), *Thais emarginata* (26), *Acanthina spirata* (21). In all other cases a single predator was used. The results of the diffusion experiments are indicated in Table 2. The test animals are listed in order of number of *Tegulas* responding to them, greatest number first.

DISCUSSION

The responses tabulated in Table 1 indicate that *Tegula* responds differently to the predators and the non-predators used in these tests. *Patiria miniata* is an omnivorous scavenger and herbivore and *Dermasterias imbricata* is thought to be a scavenger on dead animal matter, while the remainder of the test species are active carnivores, all of which have been observed eating *Tegula* either in the laboratory, in the field, or both. The survival ad-

vantages of escape behavior have been pointed out by Feder (1959), in his discussion of the food habits of *Pisaster ochraceus*. He finds that although *Tegula* is relatively abundant it is not eaten as frequently as its numbers might suggest, and that this is due, in part, to the effective escape mechanisms it has developed. Clark (1958) has been able to induce responses in herbivorous gastropods by stimulating them with carnivorous ones. The reactions are described as similar to those mentioned by Bullock (1953). *Tegula*'s response to 2 carnivorous snails, however, has been to go toward the carnivores and attempt to crawl up over them. This, too, appears to have survival value.

That the responses are stimulated by a chemical signal is indicated by the difference in type of response elicited by contact with predator tissue and clean probes. The substance appears to be diffusible in the case of starfishes and non-diffusible in the case of snails (Table 2).

While *Leptasterias aequalis* is too small to eat the larger *Tegula* specimens it can certainly eat the smaller ones, and the reactions of the large Tegulas may be a retention of a response adaptive in earlier life or to starfish in general. The one *Tegula* which gave no response to *L. aequalis* and 6 of those which gave a weak response were 20 mm in basal shell diameter or larger.

From the small number of predator species tested it is difficult to predict any correlation between sympatry of the predators and *Tegula,* and the responses of *Tegula* to the predators. However, *Pisaster brevispinus* must seldom, if ever, be encountered by *Tegula* yet this starfish elicits a strong escape reaction. It may be that there are substances peculiar to the physiology of predatory asteroids and gastropods in general which *Tegula* can recognize. If this is so then little, if any, correlation between response and sympatry of predator and *Tegula* is to be expected, but rather a correlation between feeding habit and escape reaction.

SUMMARY

The reactions of *Tegula funebralis* were tested to a number of starfishes and carnivorous snails. The responses vary according to the type of animal used as a source of the stimulus. *Tegula* flees from the contact or presence of predatory starfishes, ignores non-predaceous ones, and attempts to escape from or crawl upon the shell of the carnivorous snails used in these tests. Strong escape responses were elicited on contact with predatory starfishes such as *Pisaster ochraceus, P. brevispinus, P. giganteus, Pycnopodia helianthoides, Leptasterias aequalis* and the carnivorous snails *Thais emarginata* and *Acanthina spirata,* but not to the non-predatory sea stars *Patiria miniata* and *Dermasterias imbricata.* Escape reactions are also elicited by substances diffusing from the 5 predaceous sea stars listed above. No similar response is caused by the other test animals.

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